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# Three hands: one year later

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After one year, our hypothesis regarding the cognitive processes underlying the use of the mouth as a third hand in Neandertals (JASs forum 2014, vol. 92: 273) has achieved its main target: opening up a discussion on the possibility to investigate visuospatial functions in fossil hominids and past human populations.

Karenleigh Overmann evidences that Neandertals had more robust dental structures than modern humans, suggesting there may be a relation between dental size and the tendency to use teeth for handling objects. Recently, dental functions have been hypothesized to have influenced cranial evolutionary variations in the Neandertal lineage (Arsuaga *et al.,* 2014). Although the causal (or even adaptive) association between these two factors can be difficult to assess, this morphological difference must surely be taken into account when dealing with this behavioral issue. Overmann was totally right when considering that cognitive differences between modern humans and Neandertals could be a matter of grade, as we stated in our previous article. In fact, to date even differences between humans and chimpanzees for some medial parietal functions are more a question of degree than of brand new processes or structures (Rilling *et al.,* 2007; Barks *et al.,* 2015). We know that minor cognitive differences can generate important behavioral differences and, although the introduction of novel traits or processes can be a major force in evolution, quantitative changes should not be underestimated. Hence, if our hypothesis is correct, we should consider that, as perfectly expressed by Overmann, modern humans could be characterized by an "increased ability to engage materiality", through some changes of their visuospatial integration system. Of course, we agree that, when dealing with the general framework and larger scale of hominid evolution, postural changes were probably essential in this sense (Iriki & Taoka, 2012).

A common point raised in the commentaries deals with the adequacy of the cognitive system of Neandertals, thus with the question of whether or not such hypothesized differences in visuospatial functions can deal with better or worse performances. Overmann suggests that they were "well suited to its adaptive context" and "sufficient for them to demonstrate impressive competency and skill". A proper evaluation of the adequacy of their performance is probably beyond any experimental possibility, because it would mean dealing with functional results, cultural adaptations, and reproductive potentialities. When dealing with culture (and especially material culture), one can be induced into thinking that enhanced embodying capacities involves enhanced cultural capabilities. This is a logical form of reasoning, but it probably escapes at present a proper evaluation in terms of scientific evidence. Nonetheless, this question is probably misleading. The issue here is the visuospatial integration capacity, and not necessarily its adaptive value. In fact, a biocultural mismatch is not necessarily associated with a decrease in fitness, or even with extinction. Our species suffers from many biocultural mismatches, including drawbacks and problems associated with our biological limits and constraints in diet or posture, which are the result of different environmental selection or antagonistic pleiotropy and association between opposite adaptive effects. Despite the fact we deal with many biocultural mismatches, mostly due to our rapid cultural rate of change and large genetic inertia, our species is not currently under risk of extinction. Hence, hypothesizing that Neandertals had a different visuospatial integration capacity is different from hypothesizing that this difference could have been associated with decreased fitness, not to mention their extinction.

Concerning lithics, both Overmann and Rios-Garaizar suggest that the complexity of the Neandertal tools does not support the existence of limits in their visuospatial abilities. Spinapolice remarks however that the association between species and technology is not so linear. Even if we acknowledge the complexity of the Neandertal tools (in terms of processing, geometry, or size), we must recognize that *Homo sapiens* developed a culture which is definitely more complex and integrated, and the two levels of technical development are rather incomparable. However, for the purpose of this debate, once more this issue may be not central. In fact, it is important to notice that the production of a tool and the use of the tool involved cognitive levels which are integrated but independent. The perception of the object is based on different networks compared to the use of the object (Goodale *et al.,* 1994). Hence, the complexity of an object, and even the complexity of its productive process, should not be confounded with the capacity to embody that object within the perceptive schemes. Beyond the ability to produce the object, modern humans could have been able, in the words of Overmann, to integrate "materiality into their cognitive system in a deeper, more profound manner", allowing a "more pervasive prosthetic adaptation". This engaging capacity is not necessarily associated with the ability to produce its complexity.

The dental marks of the Neandertals and *Homo heidelbergensis* reveal a behavior which is strictly associated with these taxa, and absent (or at least far less common and extreme) in modern humans. Whatever the reasons, such specific human behavior merits attention, and possibly an interpretation. Spinapolice observes that this behavior requires small tools, which makes the behavior unlikely with the preceding (much larger) industries. This can explain, if confirmed, the absence of this behavior in more archaic hominids. At the same time, hafting can explain more efficient tooling (and hence less scratching) in modern humans. She evidences the necessity to investigate this special behavior more in depth, focusing on the kind of tools, range of activities, and context in which this behavior is associated. This is of course a mandatory step, which can be developed through both archaeological and ethnological perspectives. Finally, she focuses on language. Praxis and language have a long shared history, because these two processes largely share functions and neuroanatomical networks. There is increasing evidence associating language and motor experience (Berent *et al.,* 2015), stressing further the association between hand, body, and communication.

Carlos Lorenzo discusses the importance of the hand in primate and human phylogeny and evolution. He evidences that hand morphology in Neandertals had patent differences from hand morphology in modern humans. Generally, their structures were more robust and wider. There is a long and open debate whether or not hand morphological differences can be associated with functional differences. Some authors have hypothesized specific handling abilities for the earliest modern human populations (Niewoehner, 2001). Relying on the plasticity of human behavior, Lorenzo argues that the morphological differences of the Neandertal hands do not prevent any technical movements or action. Hence, he suggests focusing more on the whole motor system and not only on the hand anatomy. Nonetheless, probably once more we are dealing here with two different processes, which must be kept separate. The technical ability of the hand is a mechanical property, while the capacity of embodiment is a cognitive property. Any mechanical device (a robot) can simulate human hand precision (resolution and sensitivity) and power (strength). However, a mechanical device is not able to engage materiality, namely interpret the object as a body extension through a feedback able to enhance, influence and finally generate the cognitive process. A robot can be as effective as a human is, Neandertals or *Homo sapiens*, but this is not evidence of embodiment. Hence, the mechanical ability of the hand is not per se an indication of integration in terms of brain-artefact interface. The hands of the Neandertals were wide and robust. The structural organization is important not only in terms of strength or precision, but also in term of balance and response to stimulation. Dynamic touching is an essential component of the cognitive experience (Turvey & Carrello, 2011). Muscle deformation, mechanoreception, and spatial sensing are fundamental to integrate internal and external body components. This is particularly important when considering that sensing (most of all through the hands) is based on isometric stresses and tensional integrity (*tensegrity*) which makes it possible to perceive local forces globally (Ingber, 2008). Therefore, structural changes that do not influence the biomechanical properties of the hand in terms of strength and precision can however influence the capacity to transmit information on the long distance, as to be further integrated at cognitive levels.

We must stress once more that our hypothesis was proposed as an interpretation of a specific behavior (considerable use of the mouth for praxis) in the light of specific paleoneurological evidence (absence of large parietal areas, relevant for visuospatial integration and body coordination). This is important when considering the role of the body and motor functions in terms of cognitive experience, most of all within the functional complexity of the fronto-parietal system (e.g. Haggard, 2005; Iriki & Taoka, 2012). Cognitive archaeology necessarily relies on hypotheses based on the archaeological and paleontological data, which can only be partially investigated through neontological studies. Because of the impossibility to verify cognitive processes in extinct species, this field should be predominantly based on facts associated with the cultural and biological remains, possibly orientating further research in living organisms. Duilio Garofoli states that these hypotheses "can be accepted only when based upon a well-grounded method of behavioral analysis and cognitive mapping". This is, of course, not possible when working with extinct species. Garofoli stresses that our interpretation is "problematic", which is what one would expect considering the difficulties of the topic. Any hypothesis in paleoanthropology or archaeology is, in this sense, problematic. He states that we have to "demonstrate" and "explain" our "intuitions". Of course, such terms are more adequate in nuclear physics that in cognitive archaeology. He even suggests that our concept of embodiment is ambiguous, forgetting that the whole concept of embodiment is ambiguous per se, and that the scientific community has not been able, to date, to provide an effective interpretation of embodiment (Caramazza *et al.,* 2014). If we don't accept all these limits, we have to reject the whole field of cognitive archeology, or alternatively develop it on the basis of "pure epistemic requirements". We, however, prefer to adopt an intermediate position: using the available evidence to drive sensate hypotheses which can be partially evaluated in a neontological experimental context. Extreme requirements of experimental evidence can hamper the development of fruitful and interesting perspectives. On the other hand, excessive requirements of epistemological and theoretical completeness based on a strictly logical structure can reduce the debate to a purely theoretical (albeit elegant) level. This hypothesis represents a reasonable perspective based on the different and complementary available data, suggesting possible future approaches which aim to evaluate its components in both past and living populations. This is, in our opinion, a concrete and fruitful approach, and an invitation to investigate further.

As evidenced one year ago, general differences in the visuospatial integration system should be recognized in different visuospatial behaviors. Rios-Garaizar remarks that the question concerning the ability of non-modern humans to throw weapons for hunting is still open. This is certainly a fertile area that merits further attention. Ariane Burke introduces the issue of spatial integration on a larger scale, namely according to egocentric and allocentric representation of space, land, and territory. She suggested that differences in the spatial use and organization of the territories between modern humans and Neandertals could have been associated with different visuospatial capacities, which influenced the cognitive maps, the spatial perception and, finally, social structure and organization (Burke, 2012). Of course, this is an exciting and promising field for at least two reasons. First, it deals directly with the ecology of the species. Therefore, it is something intimately associated with selective factors. Second (and more specifically in regard to our topic), it is the reverse side of our medal. We can consider that body coordination (as an interface between brain and environment) and spatial mapping may represent the two main pillars of the visuospatial integration functions. The egocentric spatial processes are a bridge between the short-range (body-inside) and long range (space-outside) environment. Burke provides an efficient synthesis of this importance, and a promising perspective for testing visuospatial function in past human populations.

However, she also introduces a second issue, which may be extremely important for the interpretation of the processes associated with evolution and cognition in general: the polarity and causal relationships between neural organization and behavior. From a phylogenetic perspective, a more traditional view interprets a behavioral change as the result of a genetic/structural change supported by selective evolutionary processes. If so, a possible difference between modern humans and Neandertals for visuospatial capacity could be interpreted as the results of different phylogenetic pathways. Burke introduces a second possibility: different visuospatial abilities may have been the result of different behaviors, life-styles, and socio-cultural organization. In this case, differences may be secondary (physiological) consequences of different environmental/cultural training. Of course, these two alternatives are not mutually exclusive. Although selection and genetic changes can generate behavioral changes, the opposite is also possible: according to the "Baldwin effect", variation and behavior can direct selection, eventually promoting successive genetic assimilation (Baldwin, 1896; Crispo, 2007; Sznajder *et al.,* 2012).

The social consequences are particularly interesting. Recently, these same dental striations in Neandertals have been also hypothesized to be dependent upon sex and age, by virtue of different social tasks (Estalrrich & Rosas, 2015). Joseba Ríos-Garaizar points to a lack of collaborative behavior as a further factor that could induce the involvement of the mouth as an additional manipulative element. This comment is particularly stimulating. In primates, cranial capacity is proportional to social group size (Dunbar, 1998; Dunbar & Shultz, 2007). Group size and pair-bond relationships are strongly correlated with endorphin stimulation associated with grooming (Machin & Dunbar, 2001). That is, encephalization and social structure are intimately mediated by biochemical release induced by and associated with hand touch (Dunbar, 2010). Once more, touching is not only a matter of grip, and the hand is not only a mechanical device.

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